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[Continued on next page]

(54) Title: SYNCHRONIZATION IN PACKET-SWITCHED TELECOMMUNICATIONS SYSTEM
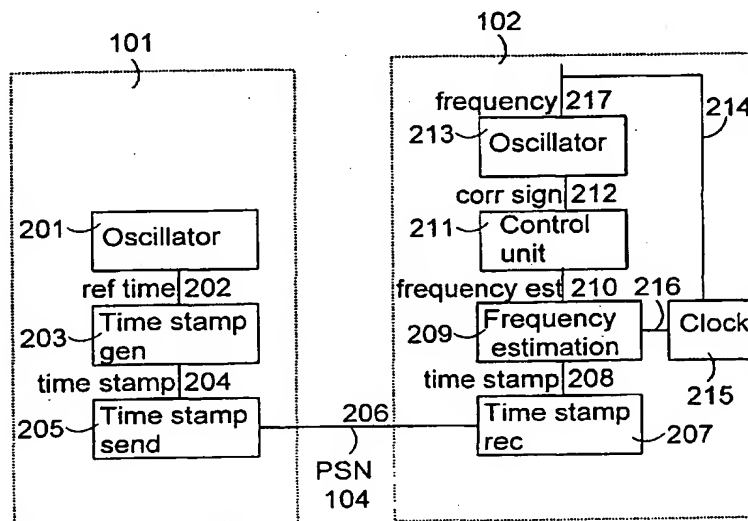
(57) Abstract: A method and equipment for providing frequency synchronization in a telecommunications system, wherein time stamps providing timing information are transferred over a packet-switched network from a transmitter network element to a receiver network element having a receiver oscillator. The expected times for reception of time stamps are estimated (i), deviations from the estimated expected time for the time stamps are calculated (ii) and at least one time stamp deviating most from the estimated expected time is removed (iii). The steps (i) - (iii) are repeated until a pre-determined number of time stamps is removed. Frequency of the receiver oscillator is then estimated using the remaining time stamps and the frequency generation of the receiver oscillator is adjusted based on the estimated frequency.

Synchronization in packet-switched telecommunications system

Background of the invention

The present invention relates to a method and equipment for synchronizing network elements over a packet-switched network.

5   A telecommunications network is a network where network elements, especially switches and base stations, need to work coherently. Oscillators in these devices are generally not accurate enough over longer time intervals and need to be adjusted in order to keep them synchronized. Timing errors are due to variations in network delay and latencies in computer hardware and software as well as clock oscillator instability.

10   ware and software as well as clock oscillator instability.

Time stamps may be used to deliver timing information for synchronization between network elements. Time stamps typically describe the time they were created according to a clock of a transmitter network element sending the time stamps. A receiving network element then tries to achieve the same timing as the transmitter by adjusting its local clock based on the re-
15   ceived time stamps. In a packet-switched network the transmission delays may vary very much and the time stamps may be delayed with a large variation in the delay.

Networks based on the IP protocol are not typically clocked since they operate asynchronously, and transmission times are highly variable and
20   unpredictable. Network Time Protocol (NTP) is a protocol used to synchronize clocks over a packet-switched network, especially over IP networks. The scope of NTP is to synchronize the absolute time values and the frequencies of the clocks involved. NTP is widely used in the Internet to synchronize computer clocks to national standard time.
25   puter clocks to national standard time.

One problem with the prior art solutions is that they do not work very well with wide variations in delay typical of packet-switched networks. In many cases it is enough to adjust the frequency of a system clock, which makes NTP unnecessarily complex for this purpose.

Brief description of the invention

30   The object of the invention is to enhance frequency synchronization in networks with variable delays. The object of the invention is achieved with a method, an apparatus and a telecommunications system which are charac-

terized by what is disclosed in the independent claims. The preferred em-
bodiments of the invention are set forth in the dependent claims.

The invention is based on adjusting frequency generation based on
estimating the frequency of a receiver oscillator to be synchronized using only
5   part of the received time stamps. Time stamps are transferred from a trans-
mitter network element (meaning any network element providing reference
timing information) to a receiver network element (meaning any network ele-
ment obtaining timing information to achieve frequency synchronization). The
expected reception times of time stamps are estimated, preferably taking all
10   time stamps in pre-determined window into account. The deviations from the
estimated expected times are calculated for time stamps and at least one time
stamp deviating most from the estimated expected time is removed. The esti-
mations, deviation calculations and time stamp removals are repeated taking
remaining time stamps into account as many times as necessary until a pre-
15   determined part of the time stamps has been removed. The frequency of the
receiver oscillator is then estimated using the remaining time stamps after the
pre-determined part of the time stamps is removed. The frequency generation
of the receiver oscillator is then adjusted based on the estimated frequency.
According to a preferred embodiment of the invention, the expected times for
20   reception of the time stamps and the oscillator frequency are estimated by
least-squares method. Also, according to an embodiment of the invention, it is
possible to remove the pre-determined number of time stamps and estimate
the frequency without using iteration.

One advantage of the invention is that synchronization can be more
25   reliably performed as the frequency of the receiver oscillator can be estimated
more accurately especially in networks with greatly variable delays. A further
advantage is that the frequency synchronization according to the invention is
easier to implement than the techniques providing time and frequency syn-
chronization. Also, no specific request for transmission of time stamps is
30   needed.

Brief description of the drawings

In the following, the invention will be described in greater detail by
means of preferred embodiments and with reference to the accompanying
drawings, in which

Figure 1 is a block diagram showing a telecommunications system according to a preferred embodiment of the invention;

Figure 2 is a block diagram illustrating a transmitter and a receiver according to a preferred embodiment of the invention;

Figure 3 is a histogram showing measurement results for simulated data traffic in a local area network;

Figure 4 is a block diagram illustrating an estimator for estimating frequency f;

Figure 5 illustrates simulation results for a local area network.

Detailed description of the invention

The invention can be used in any telecommunications system, where frequency synchronization of network elements is needed over a packet-switched network. In a preferred embodiment of the invention the network is a packet-switched local area network (LAN) yet without limiting the invention to that kind of particular network.

Figure 1 shows a telecommunications system according to a preferred embodiment of the invention where synchronization is needed between network elements over a packet-switched network. A transmitter network element (TR) 101 comprises a highly accurate clock or has access to a highly accurate clock such as an atomic clock or GPS (Global Positioning System). The transmitter 101 sends time stamps to one or more receiver network element (REC, REC2) 102, 103 over a packet-switched network (PSN) 104, such as an IP network, with variable delay. The transmitter 101 may be any kind of network element providing reference timing information to enable receivers 101, 102 to synchronize their frequencies. The receiver 102, 103 may be any kind of network element using the time stamps advantageously in order to achieve the same timing for frequency generation as the transmitter 101, that is, to achieve frequency synchronization with the transmitter 101. The synchronization is achieved based on estimating the frequency of an oscillator of the receiver 102, 103. For instance, if the system comprises a mobile network, the transmitter 101 may be a base station controller transmitting time stamps to base stations 102, 103 over a packet-switched network and the base stations 102, 103 may then build their own reference frequencies based on the time stamps.

Figure 2 illustrates elements of the transmitter 101 (the transmitter of the time stamps) and the receiver 102 (the receiver of the time stamps) relevant to the invention. The transmitter 101 comprises a reference oscillator 201 and the receiver 102 comprises a receiver oscillator to be adjusted 213.

5 The reference oscillator 201 produces reference timing information 202. The frequency of the reference oscillator 201 (reference frequency f_{ref}) is considered to be substantively constant as the transmitter 101 comprises or has access to a highly accurate clock and the receiver 102 is aware of the reference frequency. The reference frequency is advantageously stored in the memory

10 of the receiver 102 (or it may be queried from the transmitter 101). The transmitter 101 further comprises means 203 to generate time stamps 204 based on the reliable reference timing information 202 and means 205 to transmit the time stamps 206 through a packet-switched network 104 to the receiver 102. The time stamps 204 may be generated and transmitted at constant or vari-

15 able time intervals (measured by the transmitter 101) and they are preferably sent automatically without any specific request. If the time interval between consecutive time stamps is variable, the time stamps 204 comprise information on the transmit time measured by the transmitter 101.

The receiver 102 comprises means 207 to receive time stamps 206

20 from the transmitter 101 and means 209 to estimate the expected times for reception of time stamps 208 and the frequency 217 of the receiver oscillator 213. The estimation procedures according to a preferred embodiment of the invention will be described in more detail later. A local clock 215 driven 214 by the oscillator 213 is used to measure reception times of time stamps 216. A

25 control unit 211 obtains the information of the estimated frequency 210 and is used for controlling the oscillator 213 by a correction signal 212. A feedback signal from the oscillator 213 may be directly coupled to the control unit 211 (not shown). The receiver oscillator 213 is then adjusted to produce the output frequency 217 based on the correction signal 212.

30 If the frequency of the receiver oscillator 213 is f, the goal is to achieve an estimation of f, $\hat{f}$, minimizing the influence of the time deviation due to delays in the transmitter 101, the packet-switched network 104, and the receiver 102. It is assumed that the maximum time between the first and the

last time stamp that can be used in the algorithm is T_W and that the required

accuracy is $a = \left| \dfrac{f - \hat{f}}{f} \right|$. The starting point is the equation

$$X(n) = x(n) + t(n) \times \frac{f}{f_{ref}}$$, where $X(n)$ is the time for reception of

time stamp n, $x(n)$ is the delay of the same time stamp, f_{ref} is the reference

5   frequency of the reference oscillator 201 and $t(n)$ is the transmit time of time
stamp n. It is possible that the time stamps are delivered with constant time
intervals, when $t(n)$ could be replaced by $\Delta t \times n$, where Δt is predefined. If
time stamps are delivered with variable time intervals, the time stamps need to
comprise information on the transmit time $t(n)$. If $x(n)$ were independent of n,

10   then $X(n)$ would be linear in $t(n)$ with the linear coefficient $\frac{f}{f_{ref}}$. However,

$x(n)$ varies a lot in a typical packet-switched telecommunications system. In
Figure 3 the measured distribution of $x(n)$ is shown for a LAN where the data
traffic has been simulated by letting four workstations send 100 byte packages
every 5 ms. In a system considered $aT_W = 30\mu s$. As appears from Figure 3

15   that the standard deviation of $x(n)$ is much larger than that.

As a reference method the following simple estimation of f is
shown:

$$\hat{f} = \frac{X(n_0 + n_w - 1) - X(n_0)}{t(n_0 + n_w - 1) - t(n_0)} \times f_{ref} ,$$

where n_{w-1} is in this reference method the last time stamp that can

20   be used and is such that $X(n_0 + n_w - 1) - X(n_0) < T_w$. This method uses only
two values from the time series $\{X(n)\}$. In order to achieve an accuracy of a,
the error in the time difference between two time stamps must be smaller than
aT_W. The drawback of the reference method is that it is very sensible to the
wide variation in delay $x(n)$ that is typical of a packet-switched network.

25   In the following an estimation of the frequency f according to a
preferred embodiment of the invention will be described with reference to Fig-
ure 4. In the following embodiment the frequency f is estimated by least-

squares method, however, it is also possible to use some other method, for instance weighting of time stamps.

The receiver 102 comprises the estimator 209 to estimate the frequency f using advantageously a pre-defined window of time stamps, wherein the number of time stamps in the window is n_w, that is, n_w received time stamps will be used when f is estimated. The number of time stamps n_w in the window is advantageously experimentally adjusted to an optimal value, it is also possible that the window covers all received time stamps. If the time interval between consecutive time stamps in the transmitter 101 is variable, the estimator 209 comprises means to check the transmit time $t(n)$ from time stamps 208 and estimate the frequency f taking also the transmit time $t(n)$ into account.

A conventional least-squares algorithm may be used to estimate the frequency f and the expected times for the reception of the time stamps preferably taking into account all time stamps n_w in the window (at first iteration). Thus the estimator 209 comprises means 301 to estimate at least the expected times for reception $X(n)$ of the time stamps utilizing least-squares estimation, first covering all time stamps n_w in the window. By taking all time stamps n_w into account the influence of variation in $x(n)$ is reduced.

The least-squares algorithm is optimum if the sequence of the delay $x(n)$ is uncorrelated and Gaussian. However, $x(n)$ is not Gaussian, but its probability distribution function (pdf) is asymmetric with a more pronounced tail. It is possible to get the delay $x(n)$ more Gaussian-like by removing N_r time stamps that deviate most from the other time stamps. The number of time stamps to be removed, N_r, may be decided each time the synchronization is done. Preferably N_r is pre-determined, for example based on measured statistics of the network 104, accuracy demands or oscillator stability.

The estimator 209 further comprises means 302 to calculate deviations of measured reception times from the estimated expected times and means 303 to remove one or more time stamps deviating most from the expected times. A repeat loop 304 from 303 to 301 is used if the N_r number of samples have not been removed. The time stamps may be advantageously removed one by one by iteration so that estimations, deviation calculations

and time stamp removals 301 - 303 are repeated by using the repeat loop 304 for the remaining time stamps. As the N_r number of time stamps with greatest deviations are removed, the estimator 209 comprises means 305 to estimate the frequency f using the remaining time stamps. The frequency information 210 based on the estimated frequency, $\hat{f}$, may then be used for adjusting frequency generation so that frequency generation of the receiver oscillator 213 may be synchronized.

In the following the preferred embodiment of the invention is illustrated mathematically, where the estimated frequency, $\hat{f}$, is calculated by iteration.

1. The vector $\overline{X}_0 = \begin{pmatrix} X(n_0) \\ X(n_0+1) \\ \vdots \\ X(n_0+n_w-1) \end{pmatrix}$ is formed, $\overline{X}_0$ is a $n_w x1$ vector.

2. The $n_w x2$ matrix $A_0 = \begin{pmatrix} 1 & t(n_0) \\ 1 & t(n_0+1) \\ \vdots & \vdots \\ 1 & t(n_0+n_w-1) \end{pmatrix}$ is formed.

3. A linear regression estimating the frequency f and the expected times for reception, $\hat{X}_0(n) = \hat{C}_0 + t(n) \times \dfrac{\hat{f}_0}{f_{ref}}$, may be calculated by applying a conventional least-squares algorithm, taking all time stamps in the window into account. $\hat{X}_0(n)$ is the least-squares estimate for $X(n)$, $\hat{C}_0$ and $\dfrac{\hat{f}_0}{f_{ref}}$ are scalars given by the matrix equation $\begin{pmatrix} \hat{C}_0 \\ \dfrac{\hat{f}_0}{f_{ref}} \end{pmatrix} = \left(A_0^T A_0\right)^{-1} A_0^T \overline{X}_0$. C and f may be substantially simultaneously estimated, then the estimated $\hat{C}$ and $\hat{f}$ (at first iteration $\hat{C}_0$ and $\hat{f}_0$) may be used to calculate the estimate for expected times of reception $\hat{X}(n)$.

4. Deviation from the estimate $\hat{X}_0(n)$, $e_n = \left| X(n) - \hat{X}_0(n) \right|$, is calculated for time stamps from n_0 to n_0+n_w-1 .

5. It is supposed that the time stamp m deviates most from its estimated expected time, thus $m = \max \arg e_n$, that is, $e_m \geq e_n$ for all n.

6. A new vector $\overline{\mathbf{X}}_1 = \begin{pmatrix} X(n_0) \\ X(n_0 + 1) \\ \vdots \\ X(m - 1) \\ X(m + 1) \\ \vdots \\ X(n_0 + n_w - 1) \end{pmatrix}$ is formed, which is identical

to $\overline{\mathbf{X}}_0$ except that $X(m)$ has been removed. $\overline{\mathbf{X}}_1$ is thus a $(n_w - 1)x1$ vector.

7. A new $(n_w - 1)x2$ matrix $\mathbf{A}_1 = \begin{pmatrix} 1 & t(n_0) \\ 1 & t(n_0 + 1) \\ \vdots & \vdots \\ 1 & t(m - 1) \\ 1 & t(m + 1) \\ \vdots & \vdots \\ 1 & t(n_0 + n_w - 1) \end{pmatrix}$ is formed.

8. A new estimate $\hat{X}_1(n) = \hat{C}_1 + t(n) \times \hat{f}_1 / f_{ref}$ is made, where $\hat{C}_1$ and

$\hat{f}_1 / f_{ref}$ are scalars given by the matrix equation $\begin{pmatrix} \hat{C}_1 \\ \hat{f}_1 / f_{ref} \end{pmatrix} = \left(\mathbf{A}_1^T \mathbf{A}_1 \right)^{-1} \mathbf{A}_1^T \overline{\mathbf{X}}_1$.

9. Step 4 is returned and the steps 4 to 8 are repeated N_r times (the first time included). In every iteration advantageously one time stamp is removed from the equation. As N_r number of time stamps have been re-moved, the last equation is thus $\begin{pmatrix} \hat{C}_{N_r} \\ \hat{f}_{N_r} / f_{ref} \end{pmatrix} = \left(\mathbf{A}_{N_r}^T \mathbf{A}_{N_r} \right)^{-1} \mathbf{A}_{N_r}^T \overline{\mathbf{X}}_{N_r}$, where $\overline{\mathbf{X}}_{N_r}$ is

a $(n_w - N_r)x1$ vector. The final estimation for f is then $\hat{f} = \hat{f}_{N_r}$ (the frequency estimate information 210 in Figure 4) which may then be used for adjusting frequency generation of the oscillator 213. As indicated earlier (the means 301), the frequency f is advantageously estimated only in the final iteration (step 9).

According to an embodiment of the invention, it is also possible to remove the pre-determined number N_r of time stamps at once and derive the estimated frequency, $\hat{f}$, without using iteration. This means that the repeat loop 304 is not needed and f' may be estimated after the first removal of time stamps.

Referring again to Figure 2, the receiver 102 comprises means 211 (control unit) to generate a correction signal 212 for the oscillator 213 based on the information of the estimated frequency $\hat{f}$ 210. It is further possible to have feedback from oscillator output 217 to the control unit 211 (not shown).

The correction signal 212 advantageously determines the required adjustment needed in the oscillator 213. The correction signal 212 may then be sent to the oscillator 213, and the frequency 217 generation in the oscillator 213 is adjusted based on the correction signal 212 (using the frequency information 210). The local clock 215 of the receiver 102 is then also adjusted when the frequency 217 of the oscillator is changed, that is, the running of the clock is changed based on the estimated frequency.

The accurate estimation of f allows the synchronization of the frequencies produced by the oscillators 201 and 213. The oscillator 213 may generate frequencies 217 for various needs in a network element, e.g. for different functions in a transceiver or in a switch.

The need for synchronization depends very much on system characteristics, for instance on the used oscillators and network load. Advantageously the synchronization procedures described above are done every time when a time stamp is received, it is also possible to do the procedures at certain time intervals using the clock 215 of the receiver 102.

In Figure 5 simulation results are shown based on measurements of a similar system as in Figure 3. 20% of the time stamps have been removed ($N_r = 0.2n_w$). The number of time stamps in the window, n_w, has been varied from 10 to 100. Increasing the number of time stamps n_w within the window enhances the performance. The dotted line 501 refers to the reference method using the first and the last time stamps in the window only. The dashed line 502 shows the result of the plain least-squares method ($\hat{f} = \hat{f_0}$). The solid line 503 is the modified least-squares method according to the pre-

ferred embodiment of the invention. Finally the line of dots and dashes 504 indicates the required accuracy in the system.

As the simulation results show, the synchronization according to the preferred embodiment of the invention enables more accurate estimation of the frequency . This allows more accurate frequency synchronization of the receiver oscillator 213 based on the reference oscillator 201.

The present invention can be implemented to the existing network elements. They all have processors and memory with which the inventive functionality described above may be implemented. Parts of the transmitter 101 and receiver 102 according to the preferred embodiment of the invention may be implemented by means of software run in a processor. Also, it is possible to implement some functions as a hardware solution, for example by applying Application Specific Integrated Circuit (asic) or separate logic.

The present invention may be used also in mobile packet-switched networks. For instance, the invention may be used in a General Packet Radio Service (GPRS) network to provide frequency synchronization for base station.

It is obvious to one skilled in the art that as technology advances, the inventive concept can be implemented in many different ways. Hence the invention and its embodiments are not limited to the above examples, but may vary within the scope and spirit of the appended claims.

Claims

1. A method for providing frequency synchronization in a telecommunications system, wherein time stamps are created in a transmitter network element to provide timing information based on a reference oscillator of the

5   transmitter network element, the time stamps are transferred over a packet-switched network from the transmitter network element to a receiver network element, the receiver network element having a receiver oscillator, c h a r acterized by comprising the steps of:

(i) estimating expected times for reception of time stamps in the re-

10   ceiver network element,

(ii) calculating deviations from the estimated expected times for the time stamps,

(iii) removing at least one time stamp deviating most from the estimated expected time,

15   repeating the above mentioned steps (i) - (iii) by removing at least one time stamp at a time until a pre-determined part of the time stamps is removed,

estimating frequency of the receiver oscillator using the remaining time stamps after the pre-determined part of the time stamps is removed, and

20   adjusting the frequency generation of the receiver oscillator based on said estimated frequency.

2. A method according to claim 1, c h a r a c t e r i z e d by

estimating said frequency and the expected times for reception by least-squares method.

25   3. A method according to claim 1 or 2, c h a r a c t e r i z e d by

removing the pre-determined part of the time stamps at once after the deviations have been calculated for the first time.

4. A method according to any one of the preceding claims, c h a r acterized by

30   generating a correction signal based on said estimated frequency in a control unit of the receiver network element, and

adjusting the frequency generation of the receiver oscillator based on the correction signal.

5. A method according to any one of the preceding claims, c h a r a c t e r i z e d by

storing frequency of the reference oscillator in the receiver network element, and

using the stored frequency when estimating the frequency of the receiver oscillator.

6. A method according to any one of the preceding claims, c h a r a c t e r i z e d in that

time interval between consecutive time stamps in the transmitter network element is constant.

7. A method according to any one of the claims 1 - 5, c h a r a c - t e r i z e d in that

time interval between consecutive time stamps in the transmitter network element is variable and transmit time measured by the transmitter network element is given in time stamps.

8. An apparatus in a telecommunications system, said apparatus comprising means to receive time stamps providing time information and a receiver oscillator, c h a r a c t e r i z e d in that

said apparatus comprises means to estimate expected times for reception of time stamps,

said apparatus comprises means to calculate deviations from the estimated expected times for the time stamps,

said apparatus comprises means to remove at least one of the received time stamps deviating most from the estimated expected time,

said apparatus comprises means to estimate frequency of the receiver oscillator when a pre-determined part of the time stamps is removed, and

said apparatus comprises means to adjust the frequency generation of the receiver oscillator based on said estimated frequency.

9. An apparatus according to claim 8, c h a r a c t e r i z e d in that

the expected times for reception of the time stamps and said frequency are estimated by a least-squares method.

10. An apparatus according to claim 8 or 9, c h a r a c t e r i z e d in that

said apparatus comprises means to generate a correction signal based on said estimated frequency, and

said apparatus comprises means to adjust the frequency generation of the receiver oscillator based on the correction signal.

5   11. An apparatus according to any one of the claims 8 - 10, c h a r a c t e r i z e d in that

time stamps are removed one time stamp at a time repeating the estimations of the expected times and the deviation calculations until the predetermined part of the time stamps has been removed.

10   12. An apparatus according to any one of the claims 8 - 11, c h a r a c t e r i z e d in that

said apparatus comprises a local clock driven by the receiver oscillator used for measuring the reception times of time stamps.

13. An apparatus according to any one of the claims 8 - 12, 15 c h a r a c t e r i z e d in that

said apparatus is a base station of a mobile telecommunications system.

14. A telecommunications system, wherein in a transmitter network element is arranged to create time stamps to provide timing information based 20 on a reference oscillator of the transmitter network element, the transmitter network element is arranged to transfer time stamps over a packet-switched network to a receiver network element, the receiver network element having a receiver oscillator, c h a r a c t e r i z e d in that the receiver network element is arranged to:

25   (i) estimate expected times for reception of time stamps in the receiver network element,

(ii) calculate deviations from the estimated expected times for the time stamps,

(iii) remove at least one time stamp deviating most from the esti-30 mated expected time,

repeat the above mentioned steps (i) - (iii) by removing at least one time stamp at a time until a pre-determined part of the time stamps is removed,

estimate frequency of the receiver oscillator using the remaining 35 time stamps after the pre-determined part of the time stamps is removed, and

adjust the frequency generation of the receiver oscillator based on said estimated frequency.
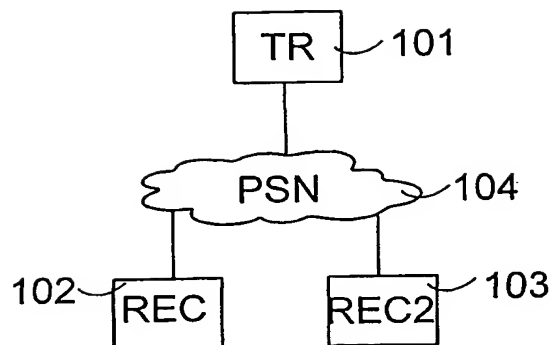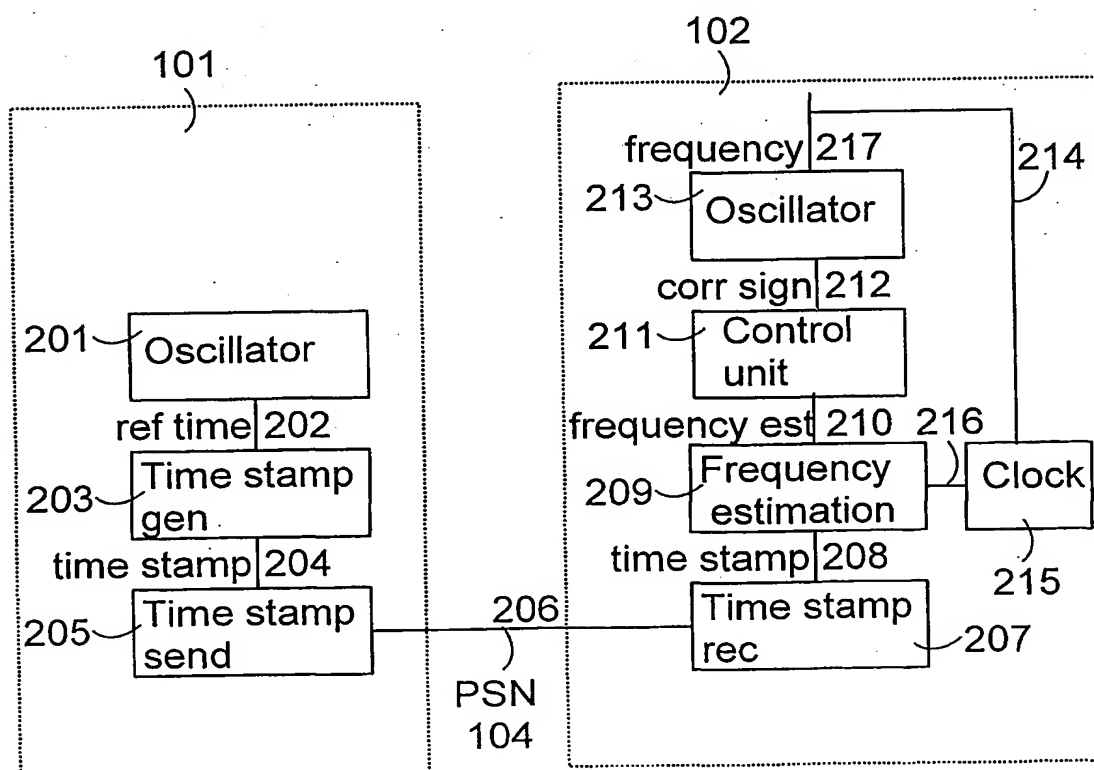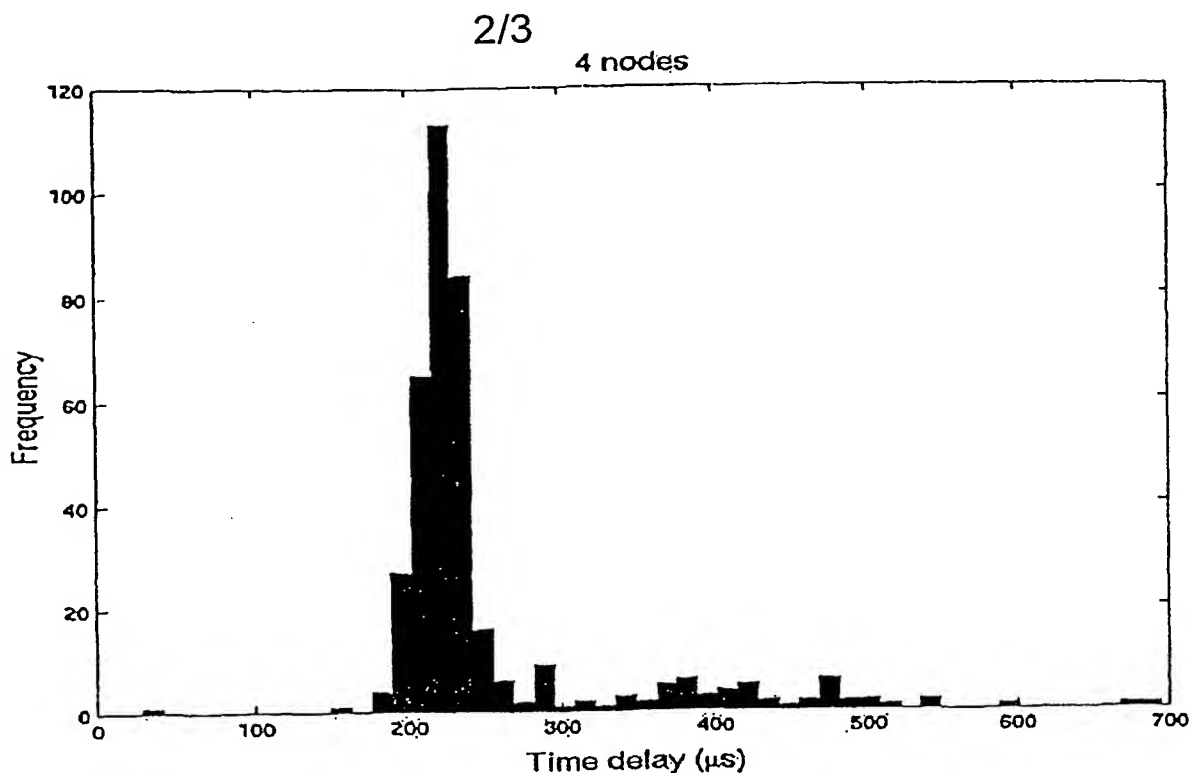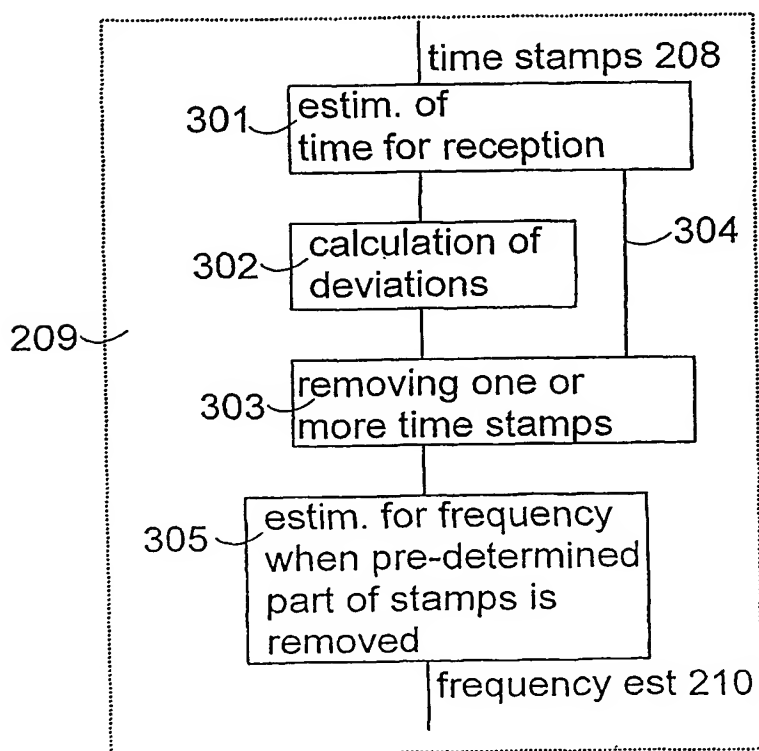
1/3

Fig. 1

Fig. 2

4 nodes

Fig. 3

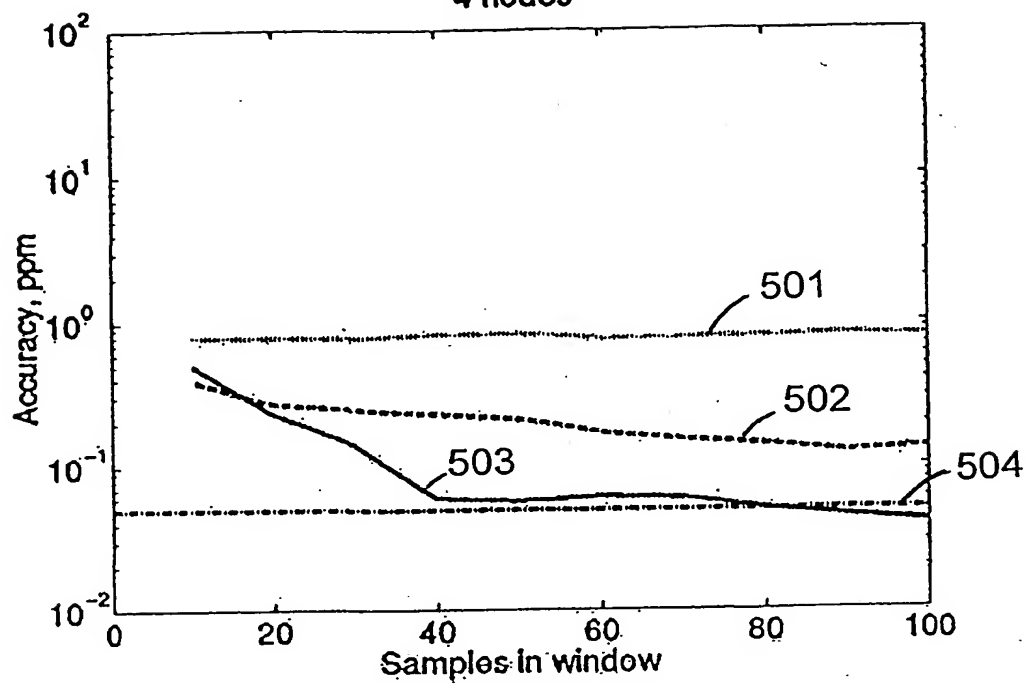

Fig. 4

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Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 00/01159

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04L 7/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04L, H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9938285 A1 (ADC TELECOMMUNICATIONS, INC.), 29 July 1999 (29.07.99), page 9, line 15 - page 10, line 6, claim 1, abstract	1-14
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A	IEEE TRANSACTIONS ON COMMUNICATIONS, Volume 43, No 2,3,4, February 1995, Richard C. Lau et al, "Synchronous Techniques for Timing Recovery in BISDN", see section IV B, V	1-14
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A	WO 0048421 A1 (KONINKLIJKE PHILIPS ELECTRONICS N.V.), 17 August 2000 (17.08.00), claim 1, abstract	1-14
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| X | Further documents are listed in the continuation of Box C. | X | See patent family annex. |

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 April 2001	2 4 -04- 2001
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Peder Gjervaldsaeter/mj Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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				US	6157646	A	05/12/00
WO	0048421	A1	17/08/00	AU	6103499	A	17/04/00
				EP	1072166	A	31/01/01
				GB	9903144	D	00/00/00
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